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Development of Gridded Area Source Emissions for the Twin Cities, Minnesota Air Quality Control Region

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Prepared for

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DEVELOPMENT OF GRIDDED AREA SOURCE EMISSIONS FOR THE TWIN CITIES, MINNESOTA AIR QUALITY CONTROL REGION

August 1976

FINAL REPORT

U.S. ENVIRONMENTAL PROTECTION AGENCY
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CHICAGO, ILLINOIS 60604

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16. ABSTRACT

The Computer Assisted Area Source Emissions procedure (CAASE) was used to allocate county total emissions to subcounty area source grid squares. The grid square system provided a continuous set of squares over the seven counties of the Twin Cities, Minnesota AQCR. Objective apportioning factors based on population, housing units, area of the grid square, or a combination of these characteristics were used for the distribution of most emission source categories. The application of these factors is included in the CAASE computer programs. The remaining emission source categories--diesel rail locomotive, aircraft operations, and waterborne vessels--were allocated on the basis of factors especially developed for this AQCR. The rationale used in this development is documented in the report.

Assuming the correctness of the totals of each category of emissions furnished to the contractor, the allocated area source emissions should provide a suitable base for air quality modeling.

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A. PURPOSE

The ultimate objective of this project has been to provide EPA Region V and the Minnesota Pollution Control Agency (MPCA) with 1974 area source emissions data for the Twin Cities Air Quality Control Region (131) in a computer-compatible form and a format suitable as input to the Climatological Dispersion Model (CDM). The Computer-Assisted Area Source Emission (CAASE) procedures were to be used to develop an appropriate system of grid squares. County total emissions (by source category) were to be allocated to the grid squares using either objective factors inherent in the CAASE procedure or subjective factors developed off-line from an analysis of the characteristics of specific source categories.

B. APPROACH AND PROCEDURE

The procedures of the CAASE method, as described in Guidelines for Air Quality Maintenance Planning and Analysis, Volume 8: Computer Assisted Area Source Emissions Gridding Procedure (EPA-450/4-74-009), were followed in detail in accomplishing the project objectives. Briefly, computer programs CAASE 1 and CAASE 2 were used to strip the Bureau of the Census MED-X* tape file of all population entries for Anoka, Carver, Dakota, Hennipen, Ramsey, Scott, and Washington Counties of Minnesota and to plot for each county an overlay chart for U.S. Geological Survey 1:250,000-scale topographic maps appropriately locating (UTM coordinates) the center of each enumeration district and depicting the associated population count by a circle of scaled radius.

The overlays of population centers and the topographic maps were used off-line as the basis for constructing an array of coterminous

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*Master Enumeration District - eXtended to include geographic coordinates.

squares, each including, as far as possible, approximately the same population. A constraint placed on the gridding by the requirements of the contract necessitated that all squares within the Minneapolis-St. Paul Urban Service District be no larger than 2 km on a side. This requirement was met. The entire seven-county area was gridded as an entity with close attention being paid to making grid square sides as nearly coincident with county boundary segments as possible. This is necessary to avoid spillover of emissions from one county to another when emission allocations are made to the squares.

From the manually drawn grid, UTM coordinates of the southwest corner and the side length in kilometers were determined for each square. Each square was also identified by county and assigned a number in an orderly sequence. These data were used with the CAASE 3 program to produce a computer-drawn array of the seven-county grid scaled to the 1:250,000 Geological Survey maps. The grid was also transferred manually to 1:24,000-scale U.S. Geological Survey maps for use in analyses to determine subjective apportioning factors for emissions and for delivery to the Minnesota Pollution Control Agency (MPCA).

Subjective apportioning factors were developed for emission source categories 32, rail locomotive, diesel; 33, 34, 35, landing and take-off cycles for military, civil, and commercial aircraft, respectively; 37, waterborne vessels, diesel; and 39, waterborne vessels, gasoline.

Objective apportioning factors, based on population, housing units, grid square area, or a combination of these characteristics, were used for the remaining emission source categories. These objective factors are included as a portion of the CAASE 4 program; the subjective

apportioning factors are manually introduced into the input deck. The CAASE 4 program was run to assign appropriate apportioning values to each grid square.

The procedures used in developing the six subjective apportioning factors were:

RAILROADS

The allocation factor used was the decimal fraction (tenths only) of the ratio of the length of railroad track (TL) in a grid square to the grid square side length (GS). (The CAASE procedure takes into consideration the actual length of the grid square side.) If there was a double track, the TL:GS ratio was multiplied by two. If there were three or more tracks, there were usually one or two through tracks; allocation factors for these through tracks were computed as above. For the remaining tracks, TL:GS was multiplied by the number of tracks, and divided by four.

ALLOCATION OF VESSELS--GASOLINE

Gasoline used for vessels was considered to be primarily consumed by pleasure craft. Subjective weighting factors for the allocation of county totals into individual grid squares were determined on the basis of water area as indicated on the USGS 1:24,000- or 1:62,500-scale maps (depending upon which scale was available for the specific area). The subjective weighting factor is simply the water area in the grid square in square kilometers. Water areas in highly urbanized areas (for example, Lake Harriet in Minneapolis) were not included.

AIRCRAFT EMISSIONS

Inventory data, in the form of landing/take-off cycles for three classes of aircraft operations--military, civil, and commercial--were

available only for Hennepin and Ramsey counties. These data represent activity at Minneapolis-St. Paul International Airport and St. Paul Downtown Airport. Since each of these airports is near county boundaries, approach and departure patterns for each extend into counties other than those in which the airports are located.

The approach and departure phases of the landing/take-off cycle produce a small fraction of the total emissions evolving from aircraft terminal operations.[1/] Further, emissions from aircraft terminal operations are relatively insignificant compared to emissions from sources surrounding airports in most cases (highways, urban-industrial activities, etc.).[2/] Accordingly, aircraft activity was subjectively distributed only to grid squares within a radius of 3 kilometers of the center of area of the runway pattern, but only within the county which the airport is located.

ALLOCATION OF VESSELS--DIESEL FUEL

Tonnages of freight carried on the several waterways in the Twin Cities AQCR and the tonnages handled by the port of Minneapolis and the port of St. Paul were determined from the U.S. Army Corps of Engineers (COE) publication Waterborne Commerce of the United States, 1974. In addition, direct conversation with the COE St. Paul District Office yielded the number of "lockages" at locks number 1, 2, St. Anthony's Falls--lower, and St. Anthony's Falls--upper, during 1974. From these

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[1/] See AP-42 Section 3.2.1.1.

[2/] See Model Verification-Aircraft Emissions Impact on Air Quality, EPA-650/4-74-049, Environmental Monitoring Series, U.S. EPA, Washington, D.C., September 1974.

data, estimates were made of the freight traffic on various reaches of the rivers. These estimates, along with approximate relative values for each reach, are shown in the figure. Since the emissions are a function of the distance travelled, the river length within each area source grid square is multiplied by the relative value for the traffic to obtain the subjective allocation factor.

The basic unit for the determination of emissions from vessels (diesel) is the fuel sales. Although these sales are determined by county, the fuel is not necessarily consumed within the county of sale. Further, when the waterway forms a boundary between counties, emissions from vessels affect both counties. The use of north-south and east-west area source grid square boundaries and constraints on fractional kilometer grid square side lengths makes impossible the inclusion of "some" of the waterway in each county. For these reasons RTI recommended that diesel fuel sales be accumulated for the entire AQCR and then redistributed to each county on the basis of the estimated consumption in each.

The procedure is shown schematically as follows:

$$\text{Grid Square Subjective Weighting Factor (WF)} = \frac{(RL)_i \times (TRV)_i}{\sum_{\text{county}} [(RL)_i \times (TRV)_i]}$$

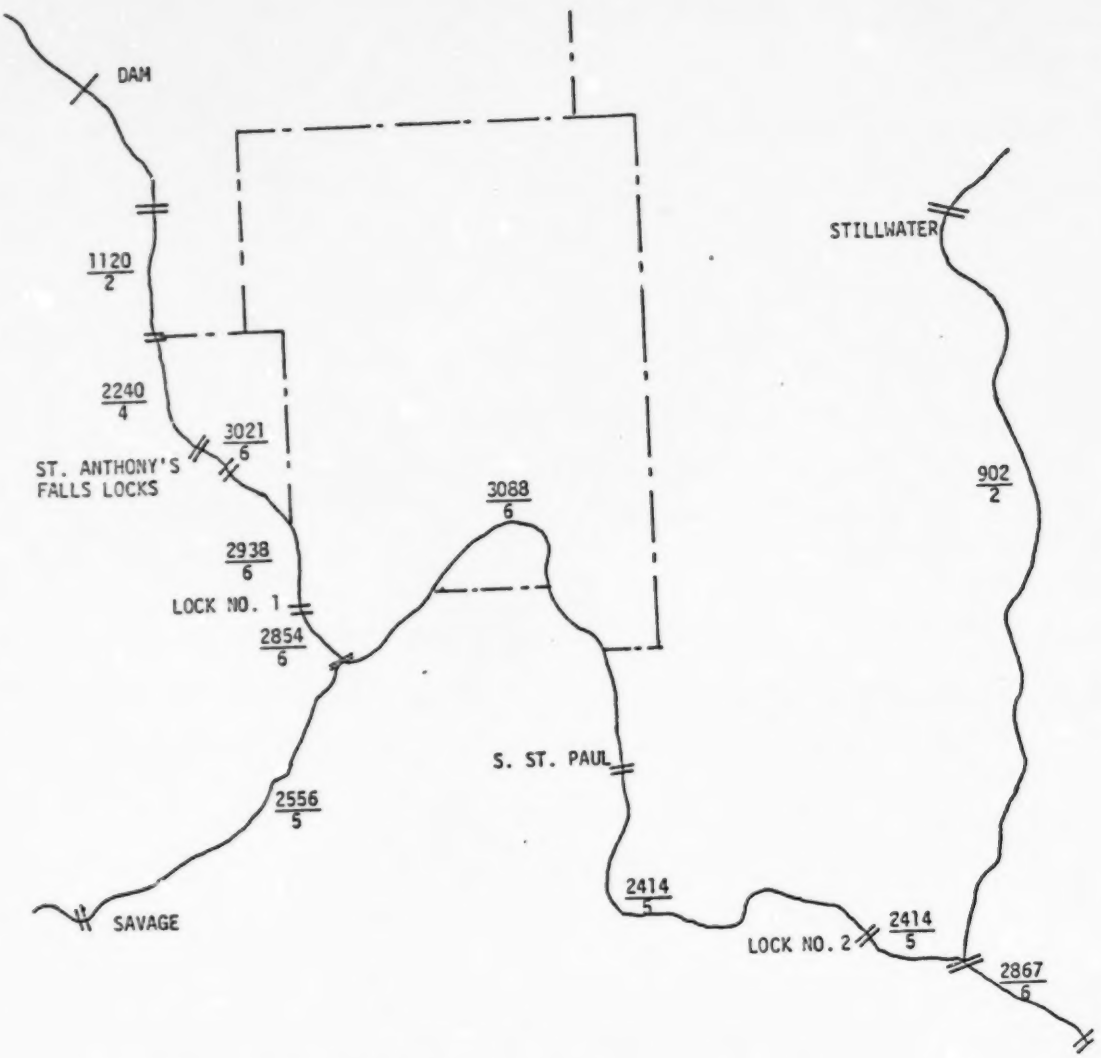
$$\text{County Diesel Fuel Allocation (FA)} = \sum_{\text{AQCR}} \text{Sales} \times \frac{\sum_{\text{county}} WF_i}{\sum_{\text{AQCR}} WF_i}$$

where

RL_i = river length within grid square i

TRV_i = traffic relative value at grid square i.

ESTIMATES OF FREIGHT TRAFFIC DURING 1974



= LIMITS OF RIVER REACHES ESTABLISHED FOR TRAFFIC ESTIMATION

2938/6 NUMBER OF TRIPS OVER THE REACH / TRAFFIC RELATIVE VALUE

The grid square subjective weighting factors, WF, are then entered on the key punch load sheets.

County diesel fuel allocation factors $\sum_{\text{county}} WF_i \div \sum_{\text{AQCR}} WF_i$ were computed for the Twin Cities AQCR. These and the 1974 fuel allocations are:

County	County Diesel Fuel Allocation Factors	1974 Fuel Allocations
Anoka	0.00125	0.03×10^4
Hennepin	0.20417	4.90×10^4
Ramsey	0.16250	3.90×10^4
Washington	0.20708	4.97×10^4
Dakota	0.41000	9.84×10^4
Scott	0.01500	0.36×10^4
Carver	-0-	-0-

These should be applied off-line to the total AQCR fuel sales to vessels to obtain each FA, the county diesel fuel allocation.

Although the foregoing procedure equitably distributes diesel fuel sales to all counties along waterways, RTI was directed to allocate the diesel fuel only to those counties reporting fuel sales. The on-line procedures of CAASE were used to allocate the diesel fuel (vessels) only to the counties for which inventories are available. These allocations were made according to the grid square subjective weighting factor, WF, entered on the load sheets for those counties.

The CAASE 5 program was used with the output from CAASE 4 to assign the appropriate fraction of each category of each county's fuels totals

to each grid square. In parallel, this program also produces the emissions attributable to the allocated fuels for each grid square. All five criteria pollutants were calculated for the Twin Cities AQCR.

C. DELIVERABLE ITEMS

The following is a list of items delivered to MPCA and/or EPA in fulfillment of this contract:

1. A computer processable deck (814 cards) of CAASE 4 override apportioning factors with each card containing the grid square ID number and the override factor for each of the six (6) area source categories to be overridden. If any of the six (6) categories were not to be overridden for that particular grid square, the field was left blank. If none were to be overridden, a card was not prepared.
2. A computer listing, with descriptive headings, for the card deck described in 1.
3. A computer processable deck (1409 cards) of Climatological Dispersion Model (CDM) input cards with grid square coordinates, side length, estimated 1974 apportioned area source emissions of SO_2 and TSP (grams/sec.), and "stack height" (ft.).
4. A computer listing, with descriptive headings, for the card deck described in 3.
5. A computer processable deck (1409 cards) of estimated 1974 apportioned area source emissions (in order, SO_2, TSP, NO_x, HC, and CO) for the AQCR formatted for input to the Implementation Planning Program (IPP) dispersion model in tons/day. All five

pollutants are on these cards as are the state and county identifier codes (EPA codes). The NO_x, HC, and CO emissions are in normaily blank fields of the IPP card format.

6. A computer listing, with descriptive headings, for the card deck described in 5.
7. A listing of the CAASE 3 input card deck, with descriptive headings, for each of the grid squares in AQCR 131. [The card deck (1409 cards) for these data was sent to MPCA when an alternative and preferred approach to dealing with highway vehicles was being considered by MPCA.]
8. Computer printouts for each of the seven counties with apportioned fuels and apportioned emissions (tons/year) for all source categories (on EPA Form (DUR) 219, 3/72) for the five pollutants: TSP, SO_2, NO_x, HC, and CO. These printouts also have for each county the total fuels input to CAASE 5; the total emissions by source-category-pollutant combination, which shows the contribution of each to the total; and the printout of the IPP card images.
9. NEDS Area Source forms for each county for 1972 fuels/throughputs.
10. NEDS Area Source forms for each county for projected 1974 fuels/throughputs.
11. The formatted version of the CAASE 5 output tape (9-track, 1600-BPI, unlabeled), externally labeled RED160.
12. The CAASE 1 (formatted) output tape containing the edited

MED-X* census data with UTM coordinates appended, externally labeled RED361.

13. The CAASE source language decks, including the "special Minnesota" modifications to CAASE 4.

14. CAASE 2 plotter outputs graphically displaying population counts and centroids of their location for each of the seven counties on a scale of 1:250,000.

15. Hand-drawn and computer-drawn (from CAASE 3) area source grid arrays for the entire seven counties on a scale of 1:250,000.

16. File descriptions of tapes RED160 and RED361.

17. All USGS topographical maps used in the completion of the project (1:250,000, 1:62,500 and 1:24,000 scales). The 1:24,000 and 1:62,500 scale maps have the grid squares drawn on them with a felt tip pen.

D. APPLICABILITY, USEFULNESS, AND LIMITATIONS OF TRANSMITTED DOCUMENTATION

The documentation submitted in the form of maps, magnetic tapes, card decks, data listings, and explantory material in fulfillment of this contract has been specifically tailored to meet the needs of the MPCA as stated in the contract and amplified in discussions among MPCA, EPA Region V, and RTI personnel.

Assuming the correctness of the totals of each category of emissions for each county and the availability of adequate monitoring data, the calibration of a standard (e.g., CDM) model should be possible using the apportioned area source emissions provided by RTI to MPCA and appro-

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*Master Enumeration District - eXtended to include geographic coordinates.

priate point source emissions data. However, since the 1974 county emissions were derived by selectively applying projection factors (supplied by MPCA) to the 1972 inventory totals, RTI has some doubts that a successful model calibration will be possible. It has been our experience that model calibration attempts usually result in uncovering deficiencies or discrepancies in emission inventories. The MPCA 1974 area source inventory, having been selectively projected from 1972, is once removed from basic data. This will make the recognition of such deficiencies or discrepancies difficult and correction even more of a problem.